JPL

Integrated Modeling of Optical Systems Workshop

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IMOS Structural Modeling

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Objectives

- Present structural analysis capabilities
- Illustrate usage for structural analysis

Objectives of IMOS Structural Capabilities

- Provide core linear FEM capability
  - Not intended to replace existing codes, but to integrate FEM capability with thermal, optical & controls in Matlab
- Provide a comfortable environment for the FEM user

Elastic Element Library

- Truss
- Beam
- Plate/membrane

Truss Element

- Provides axial stiffness only
- No bending capability
- Translation only of nodes (6 d.o.f. total)
- Used to provide engineering approximation for a long slender member where internal bending isn't important to global solution

Beam Element

- Uses standard beam theory to connect two nodes (12 d.o.f. total)
- Includes bending & transverse shear
- Exact representation of engineering beam theory
- Used when internal bending is important to global solution

Plate/Membrane Element

- Used in quadrilaterals & triangles
- Uses 5 d.o.f per node
- Similar to COSMIC NASTRAN elements
- Simplified input via uplate & splate
- General input via gplate
- Unlike truss & beam, is a continuum element, an approximation to theory of elasticity “reality”

Miscellaneous Components

- Rigid Elements & MPCs
- Lumped Mass
- Discrete Spring
- Mass Properties Analysis

Rigid Elements

- Use rbe2 for rigidly attaching a group of dependent nodes to a single independent node
- Use rbe3 for making one grid dependent upon weighted average of other independent nodes
- Use mpc for general solution — makes a given degree of freedom equal to a linear combination of other d.o.f.s

Lumped Mass

- Use conm to add mass at a node
  - scalar adds translational mass
  - vector adds diagonal of a square matrix (mass & inertia)
  - square matrix adds general mass data (full 6 x 6 inertia matrix)

Discrete Spring

- Use celas to add a spring connecting two nodes
- The spring acts in both tension & compression (required for linear analysis)

Mass Properties Analysis

- Use cg_calc to calculate center of gravity of a model
- Use wtcg to calculate mass properties of a model

Material Library

- Currently used only for plate/membrane
- Usage of mat1, mat2, mat8

mat1

- Use mat1 to provide material properties for uniform, isotropic materials
- Appropriate for all element types
- Typically used for metals

$$\sigma = E\varepsilon - \left(T - T_0\right)\alpha$$

mat2

- Used for materials which are anisotropic in 2D, such as composites
- Typically used with composite face sheets

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = \begin{bmatrix} G_{11} & G_{12} & G_{13} \\ G_{12} & G_{22} & G_{23} \\ G_{13} & G_{23} & G_{33} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} - (T - T_0) \begin{Bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_{12} \end{Bmatrix}$$

$$\begin{Bmatrix} \tau_{xz} \\ \tau_{yz} \end{Bmatrix} = \begin{bmatrix} G_{11} & G_{12} \\ G_{12} & G_{22} \end{bmatrix} \begin{Bmatrix} \gamma_{xz} \\ \gamma_{yz} \end{Bmatrix}$$

mat8

- Used for orthotropic materials in 2D
- Typically used for sandwich plate cores

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix} = \begin{bmatrix} \dfrac{E_1}{1-\nu_{12}\nu_{21}} & \dfrac{\nu_{12}E_2}{1-\nu_{12}\nu_{21}} & 0 \\ \dfrac{\nu_{12}E_2}{1-\nu_{12}\nu_{21}} & \dfrac{E_2}{1-\nu_{12}\nu_{21}} & 0 \\ 0 & 0 & G_{12} \end{bmatrix} \begin{Bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{Bmatrix} + \left(T - T_0\right) \begin{Bmatrix} \alpha_1 \\ \alpha_2 \\ 0 \end{Bmatrix}$$

$$\begin{Bmatrix} \tau_{xz} \\ \tau_{yz} \end{Bmatrix} = \begin{bmatrix} G_{1z} & 0 \\ 0 & G_{2z} \end{bmatrix} \begin{Bmatrix} \gamma_{xz} \\ \gamma_{yz} \end{Bmatrix}$$

Solution Methods

- Static
- Modal
- Modal with model reduction
- Buckling
- Static or modal with pre-load effects
- Frequency response

Static Solution

- Used to compute structural deformations due to statically applied loads
- Loads are applied at nodes
- Some capability for thermally induced loads

Modal Solution

- Create the stiffness & mass matrices
- Use eig or eigfem to compute eigenvalues & eigenvectors

Modal with Model Reduction

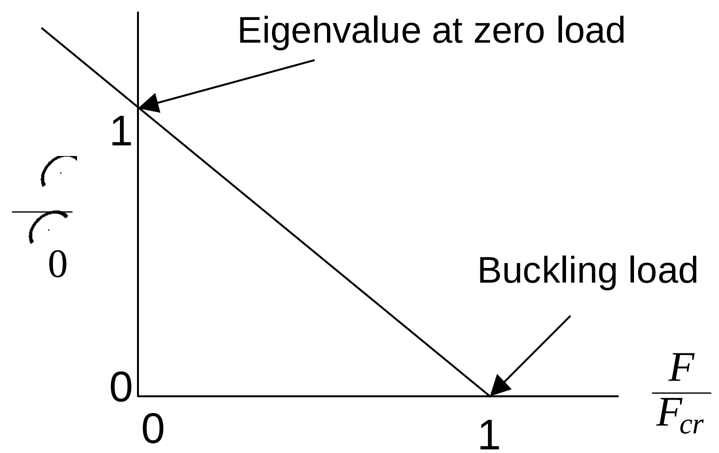
- Use Guyan reduction to reduce size of stiffness & mass matrices
  – Required when mass matrix is singular
  – Works best with a few large important masses with high kinetic energy
- Use rbmodes to compute rigid body modes

Buckling

- Beam elements will change lateral stiffness based on axial load
- Axial loads can get high enough to cause buckling

Static or modal with pre-load effects

- Axial tension/compression will change frequencies or response to static loads
- Effects are computed only for beam elements



Structural Capability Validation

- Used standard sources for code
- Sample problems and test suites
- IMOS is being used for “real world” problems
- Validated vs. test on MPI

Weaknesses

- Assumes knowledgeable user (does not restrict power user)
- Limited error checking, no hand-holding
- Incomplete forces/stress recovery
- Incomplete thermal deformation

Future Developments

- Extend force/stress recovery
- Improve thermal deformation capability
- Implement general plate (gplate)
- Introduce local coordinates
- Provide orientation of mat2 & mat8
- Provide limited substructuring
- NASTRAN converter, both ways